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(54) Image processing

(57) The more modern imaging systems employ solid state detector area arrays which "stare" at the viewed scene. The sensitivity and the output absolute value of the detector elements can vary very significantly over the array. In the invention the output of each individual detector element is normalised; specifically, there are found for each detector element the values defining its gain and offset, there are then recorded for each element the two factors that will convert each to the mean value of the entire array, and thereafter the relevant two "normalisation" factors are in use applied to the output of each element, before the output is employed to form the desired image of the viewed scene, so that the output is modified to the value it would have if it had emanated from an element having the predetermined average values for gain and offset.

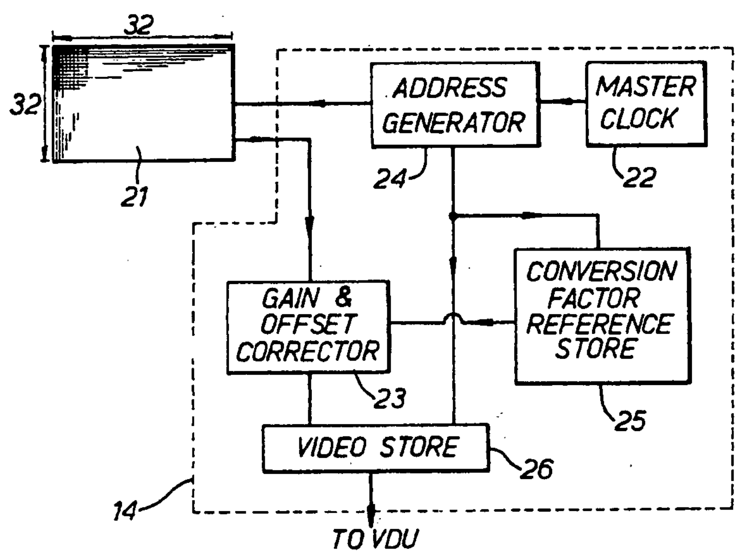

FIG. 2.

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The drawing(s) originally filed was/were informal and the print here reproduced is taken from a later filed formal copy.

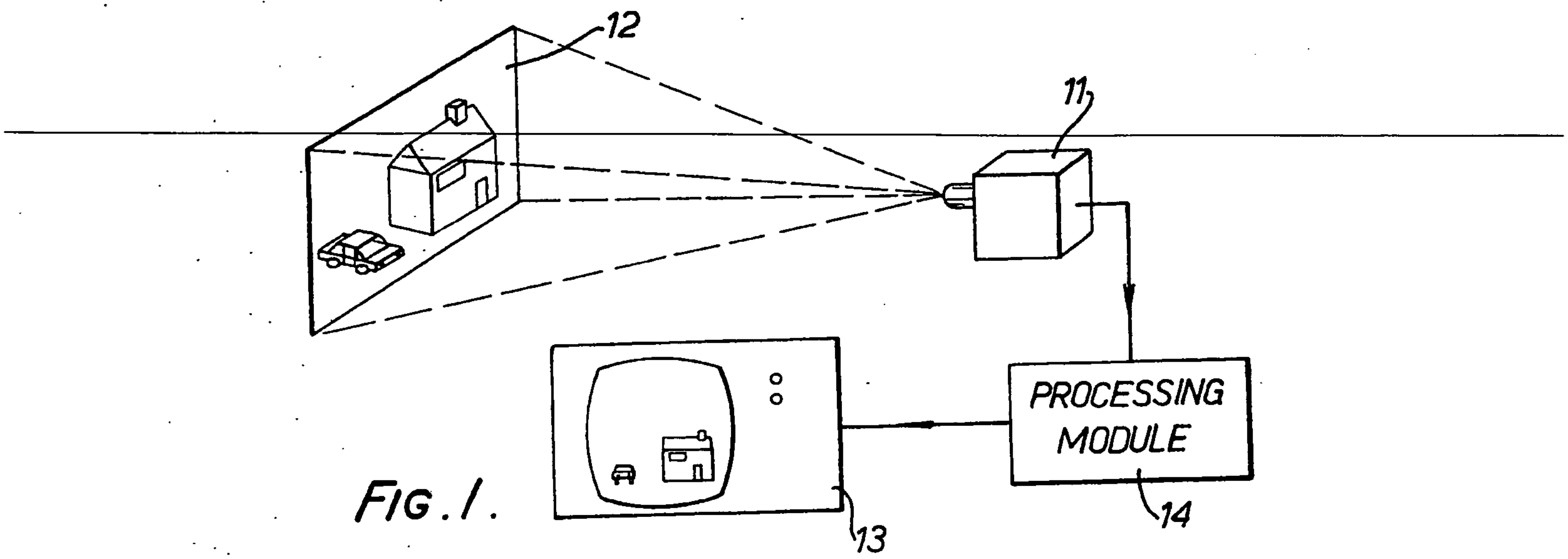
12
11
PROCESSING MODULE
14
13

FIG. 1.

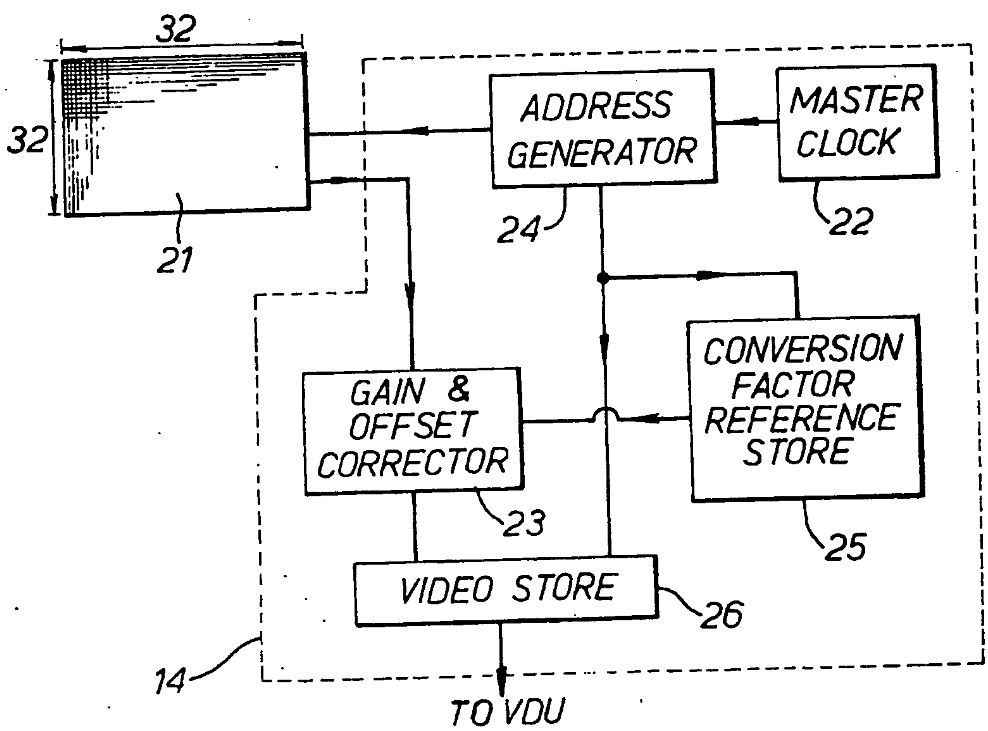
32
32
21
ADDRESS GENERATOR
24
MASTER CLOCK
22
CONVERSION FACTOR REFERENCE STORE
25
GAIN & OFFSET CORRECTOR
23
VIDEO STORE
26
14
TO VDU

FIG. 2.

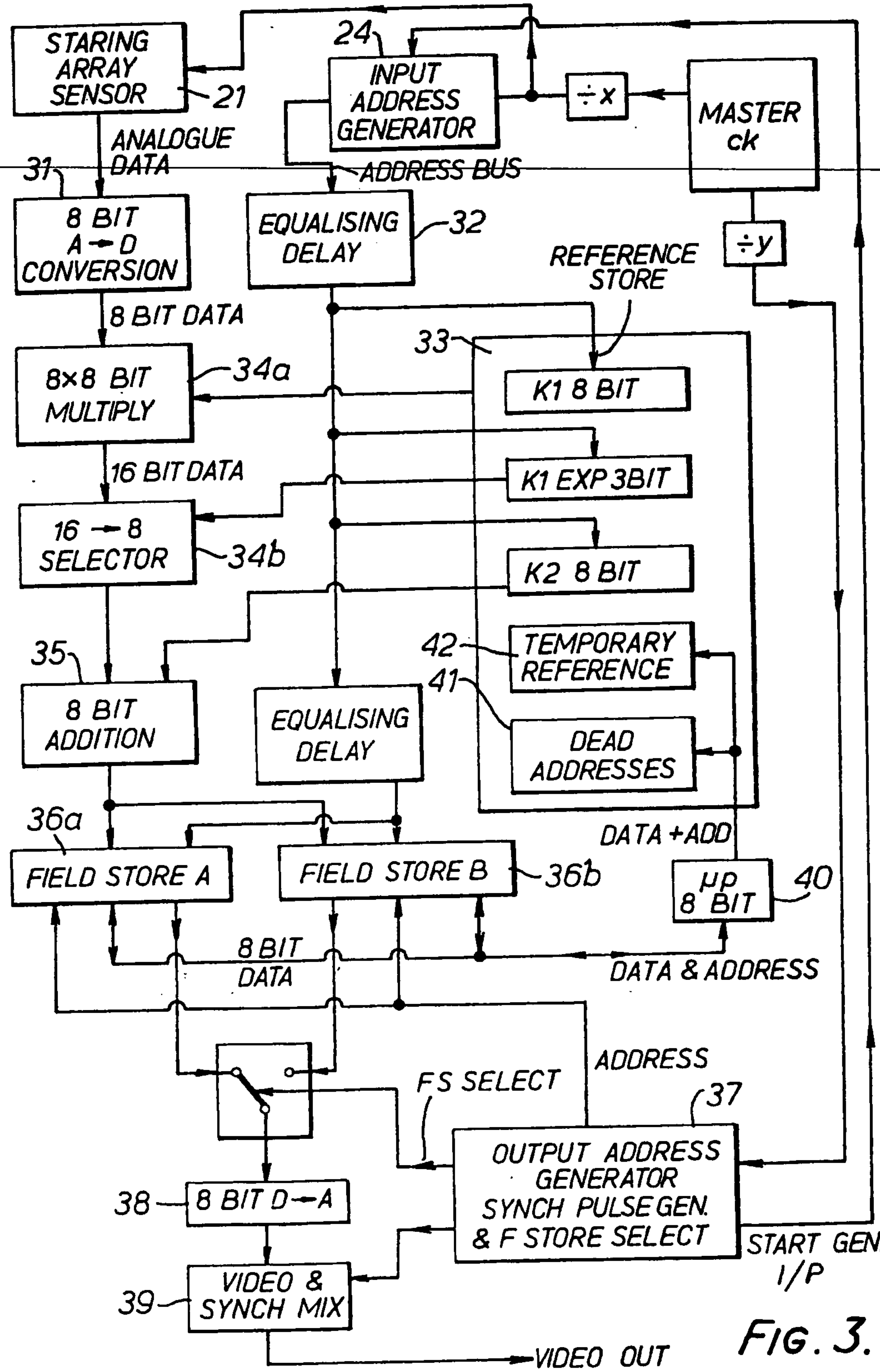
STARING ARRAY SENSOR
21
24
INPUT ADDRESS GENERATOR
÷x
MASTER ck
ANALOGUE DATA
ADDRESS BUS
31
8 BIT A→D CONVERSION
EQUALISING DELAY
32
÷y
REFERENCE STORE
8 BIT DATA
33
8×8 BIT MULTIPLY
34a
K1 8 BIT
16 BIT DATA
K1 EXP 3BIT
16 → 8 SELECTOR
34b
K2 8 BIT
35
42
TEMPORARY REFERENCE
41
8 BIT ADDITION
EQUALISING DELAY
DEAD ADDRESSES
36a
DATA +ADD
FIELD STORE A
FIELD STORE B
36b
μp 8 BIT
40
8 BIT DATA
DATA & ADDRESS
ADDRESS
FS SELECT
37
OUTPUT ADDRESS GENERATOR SYNCH PULSE GEN. & F STORE SELECT
38
8 BIT D→A
START GEN. I/P
39
VIDEO & SYNCH MIX
VIDEO OUT

FIG. 3.

SPECIFICATION

Image processing

This invention concerns image processing, and relates in particular to the processing of image data derived from a detector array, especially an infra-red detector array.

In a number of fields it is now common to supplement, or even to replace, imaging systems using visible light with corresponding systems using infra-red (IR) radiation (and referred to as thermal imaging systems). Many techniques are employed in the detection of this IR energy; one uses a single detector cell (commonly a cryogenically-cooled mercury cadmium telluride device) across which a system of rotating mirrors scans the image of the viewed scene in successively vertically displaced lines, while another uses a line of such individual detector cells across which the image is scanned as a single swathe. Detector systems of this type are, however, delicate, and expensive to construct and maintain at peak efficiency, and the more modern IR imaging systems employ solid state detector area arrays which "stare" at the viewed scene (and are thus known as "staring arrays"). These arrays are analogous to those used in present-day television cameras except that they are smaller (as few as 32 elements square as opposed to one or two thousand square) and are constructed so as to be IR sensitive rather than visible light sensitive.

Unfortunately, the current level of technology is not capable of constructing IR sensitive detector arrays with real consistency and uniformity (and indeed finds some difficulty in this respect with visible light arrays). As a result, the sensitivity (the gain in output for a specified gain in input) and the output absolute value (dependent upon both the gain and the output at some specified input level, which latter is referred to as the "offset") of the detector elements can vary very significantly over the array. Indeed, the variation is usually markedly larger than the output changes caused by the differences in radiation output of the viewed scene; this, coupled with the fact that the scene IR output (proportional to the fourth power of the absolute temperature) has a background energy level equivalent to about 300° Kelvin, so that even large differences—of 5° to 10°K—will cause small absolute changes in energy output (and thus input to the detectors), means that the raw output from the detector array is practically useless, and must first be processed in some way to provide—ultimately—a meaningful picture.

The problem may in the long term be solved by improvements in the technology enabling detector arrays—and especially IR arrays—to be constructed so that all the elements in the array have the same gain and offset. For the present, however, the invention puts forward quite a different solution, in which the output of each individual detector element is normalised (corrected to the value that an average element would give). Specifically, there are found for each detector element the values defining its gain and offset, there are then recorded for each element the two factors that will normalise these values (convert each to the mean value of the entire array), and thereafter the relevant two normalisation factors are in use applied to the output of each element, before that output is employed to form the desired image of the viewed scene, so that the output is modified to the value it would have if it had emanated from an element having the predetermined average values for gain and offset.

In one aspect, therefore, this invention provides a method of processing the output of an electromagnetic radiation detector element array to improve the quality of the image generated therefrom, in which method prior to its use to generate the image the output of each detector element is first normalised.

The nature of the detector element array may be any used or suggested for use in the Art for the relevant radiation (which may itself be visible or non-visible—IR or UV, say—light). Typical such arrays are hybrid structures of photovoltaic detectors on either a silicon CCD structure or any array of MOS switches. A specific example of a visible light array is the Integrated Photomatrix Limited IPL 2D1 (a 64 × 64 photo diode array), while an example of the CCD type of array is the Mullard M4680 (a 32 × 32 IR CCD device).

As noted hereinbefore the gain and offset of the individual detector elements within a detector array can vary widely over the array—as much as eight times the mean level gain and 80% full scale offset. For one variety of IR array the standard deviation over the mean responsivity was 0.36, which meant that more than 40% of the elements had a gain less than half or more than twice the mean gain. This is very much larger than the change in output for any one of them occasioned by a 5°K change in source temperature! Using the output of this detector array to generate directly an image (on a monochrome television set) resulted in a speckled black/grey/white display that to the human eye bore hardly any relation to the viewed scene at all. However, applying the method of the invention to the array output and then using the result to generate the image produced a quite dramatic change, forming a remarkably clear picture of the viewed scene.

In the method of the invention the output of each detector element is normalised before it is used to generate the desired image. By the word "normalised" is meant that the output value is

changed to the value that would represent the output of an average detector element under the same input conditions (and "average" means a detector element whose input/output characterstics are average when compared with those of all the elements in the array that actually work). Though there may be other ways of defining the more important operating characteristics of a detector element, it seems presently acceptable to refer solely to the gain and the offset of each element. As mentioned hereinbefore, the gain of an element is the arithmetical factor connecting change in input to change in output, while the offset is the arithmetical factor defining (with the gain) the absolute output for a specified (but arbitrary) input. Though it may not be entirely true, nevertheless at a first approximation it is satisfactory to say that a detector element's output is a linear function of its input, and may be described by the equation

$$Y = AT + B$$

(where Y is the output, T is the input—and represents the temperature of the viewed scene—and A and B are constants). A plot of Y for a range of values of T gives a straight line of slope A intersecting the "Y" axis (when T = 0) at B. The constant A is thus the gain of the element (a change in T causes A times that change in Y), while the constant B is the offset (the convenient point is with zero input—T = 0—when the element still gives an output B).

The average gain $\bar{A}$ and average offset $\bar{B}$ for a series of n elements are

$$\bar{A} = \frac{A_1 + A_2 \cdots + A_i + \cdots A_{n-1} + A_n}{n} = \frac{\sum_{i=1}^{n} A_i}{n}$$

$$\bar{B} = \frac{B_1 + B_2 \cdots + B_i + \cdots B_{n-1} + B_n}{n} = \frac{\sum_{i=1}^{n} B_i}{n}$$

and the mean output value Y^* is thus

$$Y^* = \bar{A}.T + \bar{B} \qquad (1)$$

For any particular element (the i th one):

$$Y_i = A_i.T + B_i \qquad (2)$$

$$\text{so } T = \frac{Y_i - B_i}{A_i}$$

Combining (1) and (2);

$$Y^* = \bar{A}.\frac{(Y_i - B_i)}{A_i} + \bar{B}$$

$$= \frac{\bar{A}}{A_i}.Y_i + \left(B - \frac{\bar{A}.B_i}{A_i}\right)$$

$$\text{or} \quad = K1_i.Y_i + K2_i \qquad (3)$$

$$\text{where } K1_i = \frac{\bar{A}}{A_i} \text{ and } K2_i = \bar{B} - K1.B_i$$

$K1_i$ and $K2_i$ are the gain and offset correction factors that are used to convert the output Y_i of any particular element. That output can be normalised—brought to the value that the average element would have given—by applying the two correction factors $K1_i$ and $K2_i$ special to that particular element as in (3) above. Thus:

$$Y_i^* = K1_i.Y_i + K2_i$$

where Y_i^* is the desired normalised value of Y_i.

In order to use this gain/offset normalisation technique it is necessary first to know the two correction factors $K1_i$ and $K2_i$ for each element. These may be calculated from a knowledge of the gain and offset A_i and B_i for each element—and these may in turn be calculated (assuming each element has a linear response) from a knowledge of the outputs of all the array elements at each of two input levels. In operation the procedure might be as follows:—

1) The array is pointed at a scene of uniform high temperature, and the output of each element noted.

2) The array is pointed at a scene of uniform low temperature, and the output of each element noted.

3) For each element the two outputs are then used to calculate the gain A_i and the offset B_i by solving the simultaneous equations

$$Y_{i1} = A_iT_1 + B_i$$

$$Y_{i2} = A_iT_2 + B_i$$

4) Thereafter there is calculated the average gain $\bar{A}$ and offset $\bar{B}$ for all the elements in the array.

5) Finally, there is calculated—and stored, ready for use—the two correction factors $K1_i$ and $K2_i$ applicable to each element.

When it is not satisfactory to treat the array elements' outputs as linear functions of their inputs there may instead be employed the region concept described and claimed in the Specification of our Copending Application for U.K. Letters Patent No. 8329471 (Pub. No.........) (I(6769/ELL).

Having, as a preliminary matter, obtained and stored the two correction factors for each detector element in the array, these are in operation employed to modify the value of each element's output before that output is used to construct the desired image.

The principle of this is quite straightforward; as each element is "read" to determine its output so there is retrieved from store the two correction factors applicable to that element. These are then applied to the output value, and the corrected—normalised—output value is passed on towards the image-forming apparatus. In practice it is scarcely more complicated. A particular set of equipment for performing the sequence is discussed in more detail hereinafter, but basically, using a clock system to ensure synchronisation, an address generator provides an output which identifies both the next array element to be read and the location in a store that holds the two correction values particular to that element, the element's actual output is passed into conversion means where the two correction factors are applied one after the other after they have been read out from the store, and the modified output, now in "normalised" form, is passed out of the conversion means and on to the image-forming apparatus.

The method of the invention—and specifically the normalisation calculations and the storage of the constants involved—is conveniently performed under the control of a microprocessor. A typical processor for this job is a Zilog Z80.

The image-forming apparatus will normally be a visual display unit (VDU) of the cathode ray tube (television) type, which is "written" to frame by frame and field by field to produce the desired visible image. Although conceivably the modified detector element array output could be fed directly to such a VDU it is most preferably fed via a temporary store capable of holding the output values for one whole field at a time, and thereafter sent to the VDU. Indeed, most preferably the output values data is fed to one or other of two such stores in sequence (first one store is filled, then the other) and is read out therefrom, and sent on to the VDU, from that one not presently being filled. There are two reasons why this may be desirable.

Firstly, though present-day IR-sensitive arrays are no bigger than 64 by 64 elements, future devices may have many more, and the time needed to process the outputs of these into modified form will be significant. It may indeed become the case that the time taken to fill one store is longer than the time between successive read outs. If that is so, then two stores allows one to be read while the other is being filled so that more time is available to process the data.

Secondly, the temporary storage of the modified output data means that extreme values indicative of a dead or malfunctioning detector element can quite easily be replaced by an average value obtained by extrapolation or averaging of the stored data relating to the elements adjacent the misbehaving one. It is comparatively simple to arrange that while the modified data is in the temporary store (and before it is fed to the VDU) it is examined, datum by datum (and thus store location by store location) to see whether it is of a value indicating a dead or seriously malfunctioning detector element—whether, say, it is above or below a threshold level indicative

of a "dead" detector. Where such a datum is found then the data/store locations for the adjacent elements—conveniently those four immediately above, below, to the left and to the right of the faulty element—are examined, and their values averaged to give an extrapolated value for the faulty element, which value is then placed in the relevant store location. Indeed, rather than perform this examination every time it is much preferred to effect it once—say, during the initial setting up of the apparatus, when the normalisation constants are calculated—and to store the address (the identifying location) of each of those elements that fails to provide an acceptable output. Following this, in operation it is necessary merely to look at the output values stored for the elements adjacent each of the "dead" addresses, and after averaging their values to insert the result into the sore location relevant to that of the faulty element.

An alternative method of, and apparatus for, correcting malfunctioning elements is described and claimed in the Specification of our copending Application for U.K. Letters Patent No......... (Publication No.........) (I/6770)ELL).

The invention has so far been described in terms of a method. In another aspect the invention provides apparatus for processing the output of an electromagnetic radiation detector element array to improve the quality of the image generated therefrom, which apparatus comprises means to normalise the output of each detector element prior to that output's use to generate the desired image. As will be clear from what has been said already, the normalising means is preferably means for applying to each detector's output a gain correction factor and an offset correction factor each relevant to that particular detector. This factor-applying means is itself conveniently a combination of a store (wherein are stored the gain and offset correction factors for each detector element), a multiplier and adder (to which are applied the output value to be corrected and, respectively, the gain correction factor and the offset correction factor), an address generator (to identify the next element whose output is to be modified, and to identify the relevant correction factors) and a system driver (a clock). In its more preferred forms the apparatus also includes two stores (for holding two sequential sets of modified detector array outputs) and means to switch the input to those stores, and the output therefrom to an image generator, from one to the other, and very preferably there is further incorporated means to provide for any faulty element an average output value based upon the output values for its neighbouring elements.

The invention extends, of course, to any imaging system, especially a thermal system, making use of the image-improving method or apparatus as described and claimed herein.

An embodiment of the invention is not described, though by way of illustration only, with reference to the accompanying drawings in which:—

Figure 1 is a schematic view of a thermal imaging system employing the method and apparatus of the invention;

Figure 2 is a simplified block diagram showing the method and apparatus of the invention; and

Figure 3 is a more detailed version of Fig. 2.

In Fig. 1 there is shown a thermal imaging camera (11) viewing a scene (12) and providing a visible image of that scene in a telivision-type Visual Display Unit (13) via a processing module (14). The camera 11 employs an IR detector element array (not shown separately), and the processing module 14 normalises the output of that array in accordance with the invention to enable a meaningful image to be formed on the VDU 13. The nature of the processing module 14 is shown in more detail in Fig. 2.

The camera 11 contains an IR detector element array (21 in Fig. 2, shown as a 32 × 32 matrix of elements) that is driven, by clock pulses originating in the system Master Clock (22), to output its contents element by element to a Gain and Offset Corrector (23) within the Processing Module 14. At the same time, and in synchronism, the Master Clock 22 causes an Address Generator (24) to provide the identifying address of the array element presently giving its output, and this address is sent to a Conversion Factor Store (25), causing it to output to the Gain and Offset Corrector 23 values for the Gain Correction Factor and Offset Correction Factor applicable to this particular element. The Corrector then normalises the element output (modifying it in accordance with first one and then the other Correction Factor), and outputs the resulting normalised value to the Video Store (26) where it is placed in the correct location for the relevant element as determined by that element's Address (which is also fed to the Video Store from the Address Generator 24).

In due time the contents of the Video Store are read out and passed to a VDU for display.

Fig. 3 represents a more detailed block diagram of the Processing Module 14 in Fig. 1. The hardware shown operates as follows.

The Master Clock 14 derives the Input Address Generator 24, which clocks the elements from the array 21 (the ÷x and ÷y factors are chosen conveniently to produce CCIR standard frequencly for video, and also a suitable array driving frequency), hence each element is assigned a specific address. The analogue data is converted into digital form in an 8-bit A/D

stage (31), and the address bus goes through a suitable delay (32) to keep in step with it. The address bus then accesses a reference store to obtain the two conversion factors K1 (mantissa and exponent) and K2 while the data goes to sequential multiply (34*a,b*) and addition (35) routines. As K1 and the data are both 8 bit numbers it is possible to obtain a 16 bit number in the result; the K1 exponent then determines which 8 of the 16 bits are needed to be processed further. All that is necessary for this operation to work correctly is that K1 be stored in the form $A \times 2^{-B}$, where B is as small a number as possible to allow the greatest resolution in A (thus, 128×2^{-6} is preferred to $1 \times 2^{\circ}$ as the next highest number storeable in either system is 129×2 and $2 \times 2^{\circ}$ respectively; obviously the former allows greater accuracy).

This exponent system of multiplication is chosen in preference to a standard 8 bit multiply. In the latter case, since the system is a normalisation procedure, the mean number stored as K1 is 1, and to obtain equal sensing about the mean this must be defined as a middle bit of the 8 bit number (i.e., 00010000), which in turn means that between levels of K1 the minimum change is 1 bit (i.e. 1/16th of the mean). This is equivalent to only 4 bit resolution, and is easily visible on a video picture. Also, this limits the maximum correction of gain to be × 16 or × 1/16 about the mean, which may be adequate for a staring array, but if a reasonable number of elements fall at the extremes of the correction then quantisation effects are overwhelming, e.g. an element requires to be multiplied by 1/16 to normalise its response, and its nearest neighbour is slightly lower in response, requiring a higher normalisation correction. The next highest number possible is 2/16 which may well be 50% too large.

The exponent type of multiply allows full 8 bit resolution to be maintained at × 16 and × 1/16, and only suffers from quantisation errors on the same scale at multiples of × 256 or × 1/256 of K1 is stored as 8 bits and K1 exponent stored as 3 bits.

In this way, the gain of the system is normalised, and the data then proceeds down the 'pipeline' to an 8 bit addition/subtraction (35) to normalise offsets. As this is addition, and is linear (whereas multiplication is geometric), no special techniques are required, and K2 is stored in standard 2's complement form 8 bits deep. During this processing the address of the element undergoes a further delay to ensure that processed data and address arrive at the Field Stores (36*a, b*) at the correct time. The data is stored in whichever of these Stores is in 'write' mode, determined by the Output Address Generator (37). Whichever Store is in write mode, the other is in read mode, sending data accessed by the Output Address Generator to the D→A convertor (38) and finally to a Video Synch. Mixer (39) and output. The Output Address Generator 37 changes the modes of the Field Stores (36*a,b*) after each field is read out. It also starts the Input Address Generator 24 at the same time thus ensuring that on power-up everything is synchronised to give data from the array downstream at the start of every field.

With small arrays—thus, 32 × 32 or 64 × 64 elements—the data comes downstream in less than 1 field, and so some time is left at the end of data load to the Field Stores for a Microprocessor (40) to access it and make corrections for dead elements. This is done in the following manner. The Microprocessor accesses a Dead Address Reference Store (41) and reads five addresses—that of the dead element and its four nearest neighbours. It then accesses whichever Field Store 36*a,b* is *not* being accessed by the Output Address Generator 37, and reads the data in the four neighbours, averages these (sums then and divides by four), and writes the result over what was in the dead address. It then goes back to the Reference Store and reads the next five addresses, and so on, until either all the dead elements are corrected or the system returns to a data download.

The system is used in the following way.

On power up the Microprocessor 40 writes to K1 and K2 1 and 0 respectively, so that initially the processed and raw data are identical. The array is directed at a uniform cold reference scene (preferably as cold as the minimum expected in the real scenes to be used), and the Microprocessor stores the array output for this scene in the Temporary Reference (42) assigned area of the Reference Store 33. The array is then pointed to a hot reference scene (preferably as hot as that expected in a real scene), and the Microprocessor stores the array output for this in another Temporary Reference assigned area of the Reference Store. The temperature conditions imposed on these reference scenes are merely to obtain the best linearity for the system, and as a normalisation correction is used these do not in any way represent the outer limits of the input from the scene.

The Microprocessor then calculates for each array element both A_i and B_i (see the equations referred to hereinbefore), and stores A_i where the hot reference was and B_i where the cold reference was. It then proceeds to calculate $\bar{A}$ and $\bar{B}$, and $K1_i$, $K1_i$ exp. and $K2_i$, storing these in the assigned areas of the Reference Store in turn (as the system can be left in a running mode, the picture can be observed to improve as the responses are normalised by the Microprocessor). When this is complete, the Microprocessor asks the Operator for a threshold for dead elements. This is a number which, if the response is lower, will then be called "dead". When the threshold value is input, the Microprocessor scans the A_i values and notes the addresses of any element below the given threshold along with its four nearest neighbours in the Dead Address

area 41 of the Reference Store. This done it will then proceed to interpolate for these elements every field.

As the constants and dead addresses are all software generated in the Microprocessor they can be stored in any suitable compatible medium for future use, should the calibration be impracticable.

A major advantage of the system is that since it is a normalisation the majority of the offsets of all the elements can be removed at the analogue stage, allowing only a small offset and signal to be digitised, which in turn leads to less bits required and hence lower cost. The offset is in effect useless data, which is inherent in the raw signal, and by quantising this at the A/D stage much of the resolution of the A/D may be wasted leaving only a few bits to quantise the true signal. However, by removing the offset, or the major part of it, at the analogue stage the resultant signal can effectively be quantised to a much finer degree. Such initial offset removal may be achieved using a further store with the data feeding a D/A which in turn feeds the analogue offset (stored in the additional storage area) to the −ve input of an operational amplifier. If the sensor signal is fed synchronously to the +ve input of this amplifier the output will have the majority of the offset removed at the analogue stage prior to quantisation.

The system is easily expandable to operate with larger arrays as the kernal processing is independent of sensor size.

The delay from sensor to video is at most one field, but this can be eliminated should either the sensor be driven at standard CCIR rates or should a non-TV format be required. In this case, the D/A would be connected after the kernel processing, and the Field Stores removed (except for the area for storage of reference scenes).

CLAIMS

1. A method of processing the cutput of an electromagnetic radiation detector element array to improve the quality of the image generated therefrom, in which method the ouput of each detector element is first normalised prior to its use to generate the image.

2. A method as claimed in Claim 1, in which the detector element array is a CCD IR detector array.

3. A method as claimed in either of the preceding Claims, in which the output of each detector element is normalised as regards its gain and offset.

4. A method as claimed in Claim 3, in which there are, as a preliminary matter, obtained and stored the two correction factors for the gain and the offset of each detector element in the array, these then being in operation employed to modify the value of each element's output before that output is used to construct the desired image.

5. A method as claimed in Claim 4, wherein in operation each element is "read" to determine its output, there is retrieved from store the two correction factors applicable to that element, and these are then applied to the output value, and the corrected—normalised—output value is passed on towards the image-forming apparatus.

6. A method as claimed in any of the preceding Claims, in which the image-forming apparatus is a visual display unit (VDU) of the cathode ray tube (television) type, which is "written" to frame by frame and field by field to produce the desired visible image, and the modified detector element array output is fed to such a VDU via a temporary store capable of holding the output values for one whole field at a time.

7. A method as claimed in Claim 6, in which the output values data is fed to one or other of two such stores in sequence, and is read out therefrom, and sent on to the VDU, from that one not presently being filled.

8. A method as claimed in any of the preceding Claims, in which extreme values indicative of a dead or malfunctioning detector element are replaced by an average value obtained by extrapolation or averaging of the stored data relating to the elements adjacent the misbehaving one.

9. A method as claimed in Claim 8 and Claim 7, in which while the modified data is in the temporary store (and before it is fed to the VDU) it is examined, datum by datum, to see whether it is of a value indicating a dead or seriously malfunctioning detector element, and where such a datum is found then the data/store locations for the adjacent elements are examined, and their values averaged to give an extrapolated value for the faulty element, which value is then placed in the relevant store location.

10. A method as claimed in Claim 9, in which the adjacent elements are those four immediately above, below, to the left and to the right of the faulty element.

11. A method as claimed in either of Claims 9 and 10, in which this examination is effected during the initial setting up of the apparatus, when the normalisation constants are calculated, the address of each of those elements that fails to provide an acceptable output is then stored and, in operation, looked up to identify the malfunctioning elements, the output values stored for the elements adjacent each of these then being averaged and inserted into the store location relevant to that of the faulty element.

12. A method as claimed in any of the preceding Claims and substantially as described hereinbefore.

13. Apparatus for processing the output of an electromagnetic radiation detector element array to improve the quality of the image generated therefrom, which apparatus comprises means to normalise the output of each detector element prior to that output's use to generate the desired image.

14. Apparatus as claimed in Claim 13, wherein the normalising means is means for applying to each detector's output a gain correction factor and an offset correction factor each relevant to that particular detector.

15. Apparatus as claimed in Claim 14, wherein the factor-applying means is itself a combination of a store (wherein are stored the gain and offset correction factors for each detector element), and a multiplier and adder (to which are applied the output value to be corrected and, respectively, the gain correction factor and the offset correction factor).

16. Apparatus as claimed in Claim 15, wherein the apparatus also includes two stores (for holding two sequential sets of modified detector array outputs) and means to switch the input to those stores, and the output therefrom to an image generator, from one to the other.

17. Apparatus as claimed in Claim 16, wherein there is further incorporated means to provide for any faulty element an average output value based upon the output values for its neighbouring elements.

18. Apparatus as claimed in any of Claims 13 to 17 and substantially as described hereinbefore.

19. An imaging system, especially a thermal imaging system, making use of the image-improving method or apparatus as claimed in any of the preceding Claims.

CLAIMS

New claims or amendments to claims filed on 29 June 84

Superseded claims 1, 3–4, 6–19.

New or amended claims:—

1. A method of processing the output of an electromagnetic radiation detector element array to improve the quality of the image generated therefrom by image-forming apparatus, in which method:

a value representative of the output of each detector element is first normalised prior to that value's use to generate the image; and

extreme values indicative of a dead or malfunctioning detector element are replaced by an average value obtained by extrapolation or averaging of the values relating to the elements adjacent the misbehaving one.

3. A method as claimed in either of the preceding Claims, in which the output value of each detector element is normalised as regards the element's gain and offset.

4. A method as claimed in Claim 3, in which there are, as a preliminary matter, obtained and stored the two correction factors for the gain and the offset of each detector element in the array, these then being in operation employed to normalise the value of each element's output before that value is used to generate the desired image.

6. A method as claimed in any of the preceding Claims, in which the image-forming apparatus is a visual display unit (VDU) of the cathode ray tube (television) type, which is "written" to frame by frame and field by field to produce the desired visible image, and the normalised output values are fed to such a VDU via a temporary store capable of holding the output values for one whole field at a time.

7. A method as claimed in Claim 6, in which the normalised output values are fed to one or other of two such stores in sequence, and are read out therefrom, and sent on to the VDU, from that one not presently being filled.

8. A method as claimed in Claim 6 or Claim 7, in which while the normalised output values are in the temporary store (and before they are fed to the VDU) they are examined, value by value, to see whether any one is of a value indicating a dead or seriously malfunctioning detector element, and where such a value is found then the values/store locations for the adjacent elements are examined, and their values averaged to give an extrapolated value for the faulty element, which value is then placed in the relevant store location.

9. A method as claimed in Claim 8, in which the adjacent elements are those four immediately above, below, to the left and to the right of the faulty element.

10. A method as claimed in either of Claims 8 and 9, in which this examination is effected during the initial setting up of the apparatus, when the correction factors are calculated, the address of each of those elements that fails to provide an acceptable output value is then stored and, in operation, looked up to identify the malfunctioning elements, the values stored for the elements adjacent each of these then being averaged and inserted into the store location relevant to that of the faulty element.

11. A method as claimed in any of the preceding Claims and substantially as described

hereinbefore.

12. Apparatus for processing the output of an electromagnetic radiation detector element array to improve the quality of the image generated therefrom by image-forming apparatus, which processing apparatus comprises:

means to normalise a value representative of the output of each detector element prior to that value's use to generate the desired image; and

means to provide for any faulty element an average output value based upon the output values for its neighbouring elements.

13. Apparatus as claimed in Claim 12, wherein the normalising means is means for applying to each element's output value a gain correction factor and an offset correction factor each relevant to that particular element.

14. Apparatus as claimed in Claim 13, wherein the factor-applying means is itself a combination of a store (wherein are stored the gain and offset correction factors for each detector element), and a multiplier and adder (to which are applied the output value to be corrected and, respectively the gain correction factor and the offset correction factor).

15. Apparatus as claimed in any of Claims 12 to 14, wherein the means providing an average output value comprises a temporary store capable of holding a whole array's output values, together with means for identifying stored faulty element output values and means for replacing those values with an average of the relevant element's neighbours' stored output values.

16. Apparatus as claimed in Claim 15, wherein the apparatus also includes two such temporary stores (for holding two sequential sets of normalised detector element array output values), together with means to switch the input to those stores, and the output therefrom to an image generator, from one to the other.

17. Apparatus as claimed in any of Claims 13 to 16 and substantially as described hereinbefore.

18. An imaging system, especially a thermal imaging system, making use of the image-improving method or apparatus as claimed in any of the preceding Claims.

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